BONE MAPPING IN THE INFRAZYGOMATIC REGION FOR IDEAL PLACEMENT OF TADS – A CBCT STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

BRANCH V

ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

MAY - 2018

THE TAMILNADU Dr. MGR MEDICAL UNIVERSITY

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"BONE MAPPING IN THE INFRAZYGOMATIC REGION FOR IDEAL PLACEMENT OF TADS – A CBCT STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. G. Sriram, M.D.S.,** Professor, Department of Orthodontics and Dentofacial Orthopedics, Ragas Dental College and Hospital, Chennai.

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PLAGIARISM CERTIFICATE

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This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY in BRANCH V** - Orthodontics and Dentofacial Orthopedics. It has not been submitted (partially or fully) for the award of any other degree or diploma.

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ABSTRACT

Aim:

To evaluate the cortical bone thickness in the infra-zygomatic region for ideal placement of temporary anchorage devices (TADs), by bone mapping using cone beam computed tomography (CBCT).

Materials and Methods:

CBCT images of forty subjects were randomly selected for this in-vitro study from the database available in our department. None of the subjects had noticeable periodontal disease or ectopically erupted teeth. All the reconstructed images were aligned in axial, sagittal and coronal planes.

On the 3D reconstructed CBCT images, the cortical bone thickness was measured from the cementoenamel junction towards the maxillary sinus floor at various heights of 8 mm, 10 mm, 12 mm and 14 mm along the mesial of upper first molar, middle of the crown through the furcation area of the maxillary first molar (6Middle), interdental region between the maxillary first and second molars (6-7ID), middle of the crown through the furcation area of the maxillary second molar (7Middle), distal of the maxillary second molar (7D).

Results:

The cortical bone thickness among 5 different slices, at 4 different heights are highly statistically significant (p =0.01). The cortical bone thickness gradually increased from mesial of maxillary first molar (6M) towards the interdental region between the maxillary first and second molar (6-7 ID). This gradually decreased from middle of second molar (7 Middle) towards the distal of second molar (7D).

The cortical bone thickness tended to get thicker from cementoenamel junction towards the maxillary sinus floor along the heights of 8mm, 10mm & 12mm and started to decrease towards 14mm.

Conclusion:

Based on the outcome of this study, it is reasonable to conclude that the infrazygomatic region is an optimal extra- alveolar site for placement of Temporary Anchorage Devices (TADs). The ideal site for insertion of TADs are, the interdental region between the maxillary first and second molars (6-7ID) & the middle of maxillary first molar (6 Middle) region at the heights of 10mm and 12 mm. This benefits us in achieving good primary stability. It is better to avoid placing TADs distal to maxillary second molar region as the cortical bone in that region is thinner comparatively.

Key words: *Cortical Bone, Infra-Zygomatic Crest, TADs, CBCT*

Introduction

INTRODUCTION

Anchorage has been defined as the source of resistance to the forces generated in reaction to the active components of an appliance. In simple words, it means resistance to displacement. Every orthodontic appliance consists of two elements: An active (tooth movement) and resistance element (anchorage) that makes tooth movement possible[16].

Conventional anchorage methods like headgear, elastics, adjacent teeth and etc generally rely on patient compliance and the result is unwanted reciprocal tooth movements. Anchorage loss may jeopardize a successful result because of inappropriate movement of the anchor teeth which results in insufficient space remaining to achieve the intended tooth movements. In an effort to overcome some of these problems, skeletal anchorage system has been increasingly incorporated into orthodontic treatment for over 25 years[16].

The need to eliminate undesirable effects and at the same time, to maximize anchorage, has led to the development of temporary anchorage devices (TADs). Absolute anchorage through the use of one or more mini-screws has become an integral part of modern orthodontic practice . These devices do not allow for the movement of the anchorage unit during orthodontic mechanics and they can be used 24 hours a day, offering an alternative method that better controls the side effects[48].

Cope [14] defined a TAD as : ‘A temporary anchorage device is a device that is temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obviating the need for the reactive unit altogether, and which is subsequently removed after use’.

Creekmore and **Eklund** [16]reported on the use of a surgical vitallium screw, later **Kanomi** [33]described the use of mini-screw implants for intrusion of mandibular anterior and buccal teeth.

Temporary anchorage devices (TAD) include miniplates, miniscrews, microscrews, microimplants .The advantages miniscrews include smaller size, greater number of implant sites, simpler surgical placement without any full flap retraction, immediate loading without any need for laboratory work, easier removal after treatment and lower cost[30].

Farnsworth[21] evaluated tomographic images of mandible and maxilla to define safe zones for placing miniscrews. In the maxilla, the recommended sites of insertion of miniscrews were the inter-radicular spaces between the canine and the second molar on the palatal side, and between the canine and the first molar on the buccal side. In the mandible, the recommended sites were the inter-radicular spaces between all the teeth from canine to the second molar.

TADs, when placed in the inter-radicular area pose a risk of injuring the root while inserting a miniscrew in the dento-alveolar area. It can also impede tooth movement, when the moved tooth approximates miniscrew. Therefore the best way to prevent root injury is to place TADs in the extra-alveolar site.

Extra-alveolar sites suggested for TADs include incisive fossa, canine fossa, infrazygomatic crest, premaxillary region, midpalatal region, symphysis, anterior external oblique ridge and retromolar area .These are strongly recommended when considering the risks of encountering tooth roots[80].

In addition, TADs in these areas can provide easier and wider applications in tooth movement[47], such as posterior segment intrusion, anterior teeth retraction, uprighting impacted second molar and distalisation of maxillary and mandibular molar[70].

Infra-zygomatic crest has been an obvious choice for miniscrew insertion because of the thickness of the cortical plate and its distance from the dental arch. However, **Baungaertel and Hans[2]**, stated that great individual variations exist in the thickness of the infrazygomatic crest, which is probably due to differing root lengths, maxillary sinus pneumatization, buccolingual inclination of the maxillary first molar, and the height of the alveolar processes among the individuals studied, all of which are determinants to the available bone depth for miniscrew placement.

A serious complication during miniscrew insertion in the IZ crest of adults is injury to the mesiobuccal root of the maxillary first molar. When placing mini-screws at this site for orthodontic purposes, it is important to understand the anatomical variations present in this area.

In recent years, CBCT has become a main tool for oral and maxillofacial diagnostic imaging because of its low radiation exposure, short scanning time, and high definition[28]. Also it is extremely important to conduct studies that assess bone thickness in the infrazygomatic crest for placement of TADs, providing safer surgical procedures and minimizing possible failures. An understanding of the cortical bone thickness in the maxilla and mandible not only has descriptive benefits, but clinical implications as well.

Aim of the Study:

The aim of this study is to evaluate the cortical bone thickness in the infra-zygomatic region for ideal placement of temporary anchorage devices (TADs), by bone mapping using cone beam computed tomography (CBCT).

Review of Literature

REVIEW OF LITERATURE

- **Cone beam computed Tomography**
- **Temporary Anchorage Devices**
- **Cortical bone thickness in the infrazygomatic region**

Scarfe et al. 2006[68], reviewed Cone-beam computed tomography (CBCT) systems designed for imaging hard tissues of the maxillofacial region and stated that it is capable of providing sub-millimetre resolution in images of high diagnostic quality, with short scanning times (10-70 seconds) and radiation dosages reportedly up to 15 times lower than those of conventional CT scans, which increased the availability of this technology provided the clinician with an imaging modality capable of providing a 3-dimensional representation of the maxillofacial skeleton with minimal distortion.

Maria et al. 2008[45], compared the radiation doses for conventional panoramic and cephalometric imaging with the doses for 2 different CBCT units and a multi-slice CT unit in orthodontic practice and stated that the effective dose was lower for panoramic and lateral cephalometric device (10.4 _Sv), and highest for multi-slice CT (429.7 _Sv).

Therefore from the dose to the patient point of view, the routine use of CBCT is not recommended in orthodontic procedures, because conventional images deliver lower doses to patients. However, when 3D imaging is required in orthodontic practice, CBCT should be preferred over multi-slice CT.

De Vos W et al. 2009[18], reviewed the benefits of Cone beam Computed Tomography systems over medical CT for orthodontic treatment and planning, which included a lower radiation dose to the patient, shorter acquisition times for the resolution desired in orthodontics, and significantly lower cost than medical CT. The limitations associated with CBCT scanners are increased scatter radiation, limited dynamic range of X-ray area detectors, and beam hardening artifacts.

Ribeiro et al, 2010[63] analyzed the rapid maxillary expansion using CBCT and reported that the lateral repositioning of the maxilla and increased basal bone can be accurately observed which confirms the marked morphological changes that occur in the upper arch and nasomaxillary structure.

They concluded that CBCT is a ground-breaking diagnostic method in dentistry as it provides high dimensional accuracy of the facial structures and a reliable method for quantifying the behaviour of the maxillary halves, dental tipping, bone formation at the suture in the three planes of space, as well as alveolar bone resorption and other consequences of palatal expansion.

Timock A M et al. 2011[73], investigated the accuracy and reliability of buccal alveolar bone height and thickness measurements derived from CBCT images, it stated that the mean absolute errors between CBCT and direct measurements of buccal bone height and buccal bone thickness were small (0.30 and 0.13 mm, respectively) which was statistically insignificant .The 95% limits of agreement in the submillimeter range were observed for both buccal bone height and buccal bone thickness (between _0.77 and 0.81 mm, and between _0.32 and 0.38 mm, respectively).

They concluded that under simulated clinical settings, CBCT imaging can provide accurate and reliable representations of buccal alveolar bone dimensions.

Mah et al, 2011[44], CBCT allows for visualization within the alveolar bone volume for sclerotic phenomenon that produce local intra-alveolar bone densities which vary in size from a diameter of 2 to 3 mm to 1 to 2 cm. A very high proportion of the lesions, between 88% and 100%, are found in the mandible. Within the mandible, most of the lesions are noted in the premolar and molar region. An orthodontist may use this valuable information to preclude certain types of biomechanics, such as torqueing or protraction or retraction of teeth through the affected area.

For placement of TADs, CBCT allows for visualization of the interproximal root space, palatal cortical bone thickness, sinus morphology, and other critical structures for proper selection of TAD length. In addition, assessment of bone density is possible from the volumetric data which allows selection of an ideal site for placement of TADs.

In recent trends a number of orthodontic diagnosis and treatment plan changes varied widely by patient characteristics. The most frequently reported diagnosis and treatment plan changes were in patients with unerupted teeth, severe root resorption, or severe skeletal discrepancies.

Hodges et al, 2013[26], supported that obtaining a CBCT scan before orthodontic diagnosis and treatment planning is necessary when a patient has an unerupted tooth with delayed eruption or a questionable location, severe root resorption as diagnosed with a periapical or panoramic radiograph, or a severe skeletal discrepancy. He proposed that CBCT scans should be ordered only when there is clear, specific, individual clinical justification.

Fernanda et al. 2013[23], presented a novel classification method for individual assessment of midpalatal suture morphology using CBCT. They identified and defined five stages of maturation of the midpalatal suture. Stage A, straight high-density sutural line, with no or little interdigitation; Stage B, scalloped appearance of the high-density sutural line; Stage C, 2 parallel, scalloped, high-density lines that were close to each other, separated in some areas by small low-density spaces; Stage D, fusion completed in the palatine bone, with no evidence of a suture; and Stage E, fusion anteriorly in the maxilla.

They concluded that this new classification method has the potential to avoid the side effects of rapid maxillary expansion failure or unnecessary surgically assisted rapid maxillary expansion for late adolescents and young adults.

The heightened use of cone-beam computed tomography in orthodontics has been coupled with increasing concern about the long-term risks of x-ray exposure in orthodontic patients.

Ludlow et al. 2013[42], calculated the effective doses in various combinations of field of view size and field location comparing child and adult anthropomorphic phantoms. Scan protocols used were high resolution (360 degrees rotation, 600 image frames, 120 kV[p], 5 mA, 7.4 seconds), standard (360 degrees, 300 frames, 120 kV[p], 5 mA, 3.7 seconds), QuickScan (180 degrees, 160 frames, 120 kV[p], 5 mA, 2 seconds), and QuickScan+ (180 degrees, 160 frames, 90 kV[p], 3 mA, 2 seconds).

Contrast-to-noise ratio was calculated as a quantitative measure of image quality for the various exposure options using the QUART DVT phantom. QuickScan+ effective doses were comparable with conventional panoramic examinations. Significant dose reductions are accompanied by significant reductions in image quality.

Suomalainen.A et al. 2014[72], quantified the outcome of SABG (secondary alveolar bone graft) in children with unilateral cleft lip and palate using CBCT . CBCT images taken 6 months after SABG of 35 patients were analysed. Vertical and horizontal bone supports of the grafted bone at three levels of the roots of the adjacent teeth were classified, the height of the nasal floor was compared with the unaffected side, and the inter- and intraexaminer reproducibility of these evaluations was assessed.

They concluded that the vertical height, thickness, and localization of the bone graft were possible to be evaluated. CBCT permits to assess the presence and spatial location of the alveolar bone graft when measured under standardized outcome criteria for SABG.

Shilpa Kalra et al. 2014[32], compared the accuracy of two-dimensional radiographs with a cone beam computed tomography (CBCT) for mini-implant placement. An ideal site for mini-implant placement at the buccal interradicular space between the second premolar and the first molar was determined for 40 sites (in 13 patients aged 14 to 28 years) by using CBCT data. The mini-implant placement procedure was then divided into two groups.

In CBCT group, mini-implants were placed at the sites determined from CBCT data. In RVG group, mini-implants were placed with the help of two-dimensional digital radiographs and a custom made guide. Post placement CBCT scans were obtained to determine the accuracy of the mini-implant placement.

They concluded that CBCT provides accurate three dimensional visualization of the inter-radicular space, two-dimensional intraoral radiographs seem to provide sufficient information for mini-implant placement.

Considering the high cost and higher radiation dose as compared to two-dimensional radiographs, the routine use of CBCT is not recommended for orthodontic mini-implant placement. However, if mini-implant placement is difficult because of complex anatomy such as an expanded sinus or alveolar bone loss, the use of CBCT data for planning may be considered.

TEMPORARY ANCHORAGE DEVICES (TADs)

Temporary anchorage device (TAD) is a device that is temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obviating the need for the reactive unit altogether, and which is subsequently removed after use. **Cope 2005 [14],**

Anchorage :

Freudenthaler 2001[24] - Anchorage in orthodontics is defined as the amount of allowed movement of the reactive unit in a force system.

Another definition of anchorage as given by **Daskalogiannakis & Ammann 2000[17],** states that "anchorage is resistance to unwanted tooth movement". In many situations, movement of the reactive unit is desirable, but quite frequently it is critical for the reactive unit in the orthodontic system to remain absolutely stationary while the active unit is moved in its desired direction.

Papadopoulos &Tarawneh 2007[59]; Cope JB[14] Miniscrew implants or MSIs, have also been referred to as: microimplant, microscrew implant, mini-implant, mini dental implant, miniscrew, temporary anchorage device (TAD), and OrthoImplant.

According to **Cope JB[14],** Micro- is an inappropriate term, since it is derived from microscopic or something so small that it can only be visualized with a microscope.

Sung et al. 2006[71] disagrees saying that micro- can be used to emphasize small size such as in the terms microsomia, micrognathia, microdontia and that “micro” should be used for implants smaller than 1.9mm and “mini” for implants greater than 1.9mm, but still much smaller than traditional dental implants.

Misch, 1988[51], classified the density of bone present in the maxilla and mandible as D1, a dense cortical bone mostly seen in the anterior mandible at less than 1250 Hounsfield units, then D2, a porous cortical and coarse trabecular bone quality present commonly in the anterior and posterior mandible and anterior maxilla which can be viewed at 850 to 1250 Hounsfield units, then D3, a thin porous cortical and coarse trabecular bone seen in the posterior mandible, anterior and posterior viewed at 350 to 850 Hounsfield units, and D4, a fine trabecular bone seen in the posterior maxilla viewed at 150-350 Hounsfield units.

Retention

Retention of MSIs in bone depends on different influencing factors such as a) the miniscrew implant type, the miniscrew implant dimensions b) the implant surface characteristics **Kim et al. 2009[35],** c) the insertion angle **Wilmes, Su &Drescher 2008[77],** d) the drilling hole size e) the insertion torque **Motoyoshi et al. 2006[55],** f) the force magnitude **Cheng et al[9]**. g) the anatomic location **Wiechmann et al[76].** quality and quantity of the bone, the soft tissue characteristics **Cheng et al[9].** and inflammation of the peri-implant area **Miyawaki et al. 200352.**

Stability of Mini-Implant

Marquezan et al. 2011[46], Meredith et al[49]. When discussing miniscrew implant stability and retention, it is important to define and understand the influence of both primary and secondary stability separately. Primary stability is a function of the mechanical retention between the miniscrew implants threads and the bone, and expresses the initial stability of a recently placed miniscrew implants**.** It is most often indirectly measured by the moment of force required to screw the miniscrew implant into the bone. This force is most commonly referred to as "insertion torque" **Meredith et al.**

Chen et al. 2009[8], performed a systematic review of the literature**,** which identified primary stability, measured by insertion torque, as the most critical factor for the success of miniscrew implant**.** If primary stability is not adequate following implantation, the implant-bone interface is weakened and resulting miniscrew implant micro-motion can cause failure **Chen, Kyung, et al. 2009[8].**

Javed et al. 2011[31], states that the primary stability, which is important for MSI survival, is measured in most studies by means of the insertion torque or pull out strength.

Meredith[49]; Baumgaertel 2010[4], Secondary stability is a consequence of bony remodeling at the MSI bone interface and refers to the MSI's stability after the placement site has healed. It represents the maintenance of stability as a result of localized healing and bony remodeling, with the possibility of new bone formation at the interface. Secondary stability is mainly dependent on the host's response to the MSI and is influenced by several factors.

The success rates of orthodontic microimplants have been reported differently because of several variables. In addition, many studies have recently been performed to determine factors affecting their success rates. Among them, root proximity to the orthodontic implant, cortical bone thickness, and placement angle have been reported frequently.

Yi-Ra Jung et al. 2011[81], examined microimplants implanted into the maxillary buccal alveolar bone at the midpoint between the roots of the adjacent teeth, and immediately loaded with orthodontic forces of about 50 to 200 g with elastic chains, Vertical and horizontal placement angles were determined by measuring the occlusal and mesial angles between the bone surface and the orthodontic microimplant’s long axis on the reoriented coronal and axial views of the CBCT images, respectively.

Vertical and horizontal placement angles and cortical bone thickness are not significantly related to the success rate of orthodontic microimplants, but root proximity is significantly related to their success.

Cortical bone thickness is significantly related to the vertical and horizontal placement angles, but root proximity is not significantly related to the vertical and horizontal placement angles.

Factors Affecting Mini-Implant Failure Rates

Primary stability has been shown to be the most critical factor for the success of orthodontic MSI **Chen, Kyung, et al. 2009[8].** A review of literature identifies several factors that affect the insertion torques reached and resulting primary stability of miniscrew implants. It has been well established that when comparing screws of varying size, an increase in miniscrew implants diameter has a very strong influence on peak insertion torques reached **Lim et al. 2008[38],** while MSI length influences insertion torque to a lesser degree **Kim et al. 2009[35].**

Wilmes &Drescher 2008[77], Numerous studies have shown that tapered screws reach significantly higher insertion torques, explained by the gradual increase in diameter on insertion**. Wilmes & Drescher 2011[78],**

Cortical bone thickness plays a significant role in MSI primary stability since thicker layers of compact bone cause increased placement resistance**.**

Uemura et al. 2012[74], also well documented is the effect of MSI site preparation on insertion torques reached. The presence of a pilot hole decreases insertion torques due to decreased bone-to-metal contact, while the size of the pilot hole is inversely proportional to the implant primary stability.

Devlin et al. 1998[20], of all factors studied, it is generally agreed that the alveolar bone quality, cortical bone thickness and insertion torque are among the most important factors for achieving good primary stability. Regional differences in jaw anatomy and bone structure may explain some of the variation in clinical success rate between the maxilla and mandible**.**

Additional factors discussed in the literature affecting implant primary stability include: thread design, MSI surface area, insertion depth, insertion angle and bone quality related to age of the patient **Motoyoshi et al. 2010[56].**

Thickness is a measure of the quantity of cortical bone. **Bloom RA et al, 1980[5]**, stated that measuring cortical thickness, if not the best, is a good to way to estimate bone mineralization**.**

Deguchi et al. 2006[19]., conducted a study to measure the cortical bone thickness of various potential miniscrew implant placement sites in the maxilla and mandible using CT scans from 10 adults . Measurements were taken at two vertical levels in the buccal region of the mandible and in buccal and lingual regions of the maxilla. Those levels were specified as being at the occlusal level (3-4 mm apical to the gingival margin) and at the apical level (6-7 mm apical to the gingival margin). The common mini-screw implant sites measured were mesial and distal to the first molar and distal to the second molar.

Cortical bone thickness, however, varied significantly at certain sites within and between the maxilla and mandible. Significantly less cortical bone was seen in the maxillary buccal region at the occlusal level distal to the second molar when compared with other areas in the maxilla.

Additionally, maxillary cortical bone was significantly thicker on the lingual side of the second molar site when compared to the buccal side. In the mandible, there was significantly more cortical bone mesial and distal to the second molar when compared with the maxilla.

No significant difference between vertical locations was noted within either the mandible or the maxilla. Yet, there was a significant difference between the mandible and maxilla at the different vertical heights. There was significantly more cortical bone in the mandibular molar region than the same region of the maxilla. This finding is consistent with that of **Peterson et al. 2006[61].**

Motoyoshi, et al. 2007[54], in the cross sections mesial to the first molar, the average cortical bone thickness ranged from 1.09 to 1.62 mm in the maxilla and 1.59 to 2.66 mm in the mandible and inclined to increase with height. In cross sections distal to the first molar, the average cortical bone thickness ranged from 1.14 to 2.12 mm in the maxilla and 2.10 to 3.03 mm in the mandible.

The cortical bone thickness of the mandible in adolescents was thinner than in adults at heights of 3–8 mm. No significant difference in cortical bone thickness was observed in the mandible according to gender. Thus the morphometric analysis revealed that the cortical bone of the mandible was significantly thicker than that of the maxilla at any location in the buccal posterior region, and the mandible suffices as a preparation site for mini-implants.

Bone quality is known to be one of the major factors in the stability of miniscrews. Since mandibular second molar region has thinner cortical bone than mandibular third molar region so could show a lower success rate. **Cheol-Hyun Moon 2008[11].**

Friberg et al 1995[25]., studied bone quality using six mandibles and four maxillas of adult cadavers to demonstrate the cutting resistance (i.e., friction) experienced when placing 31 endosseous titanium implants into 31 threaded canals. Bone area measurements were performed around the implants. The cutting resistance values, together with the total bone area values, were higher in the mandible than in the maxilla.

The results of the study showed that there was a tendency for higher cutting resistance values were seen in the incisor area than in the premolar area of both the maxilla and mandible. The correlation between cutting resistance and bone density was statistically significant, indicating that increase in the cutting resistance is directly proportional to the bone density. The more resistance experienced, the more dense the bone.

Therefore, based on this study, bone density is increased in mandible than in the maxilla, and within each jaw, bone tended to be denser in the incisor region than that of the premolars.

The study draws a conclusion that there are differences in bone density, between maxilla and mandible, as well as within each jaw. Therefore an understanding of the quantity and quality of bone is of prime importance for placing temporary anchorage devices.

Cortical bone thickness in infrazygomatic region

Santos et al. 2017[66], Evaluated the infrazygomatic crest region thickness in adult (male and female) patients using Cone-beam computerized tomography (CBCT) images from 40 patients , at thickness 2 mm above the distobuccal root of the permanent maxillary first molar (Measurement 1), and 2 mm above the first measurement (Measurement 2). They concluded that the mean thickness of the infrazygomatic crest in males was 3.55 mm for measurement 1 and 2.84 mm for measurement 2, while in females these were

2.37mm and 2.24mm , respectively and the overall mean thickness of the infrazygomatic crest was 2.49 mm with respect to measurement 1, and 2.29 mm for measurement 2, with no statistically significant differences between gender.

Baumgaertel et al. 2009 [3], When inserting orthodontic mini-screws (6 mm or longer) into the infrazygomatic crest, perforation of the maxillary sinus or the nasal cavity can be expected. However, the anatomy at this site varies considerably between individuals.

Hence they investigated the bone depth at the infrazygomatic crest with regard to orthodontic mini-screw insertion. They stated that the greatest bone depth was available at, on average, 11.48 +/- 1.92 mm apical from the cemento-enamel junction of the maxillary first molar and decreased rapidly further apically. Maximum bone depth (7.05 +/- 3.7 mm) was present at the lowest measurement level.

However, here, insufficient clearance to the molar roots was present. Both the measurement site and the level at which the measurements were conducted had a significant impact on bone depth.

Farnsworth et al.2011[21], assessed age, sex, and regional differences in the cortical bone thickness of commonly used maxillary and mandibular miniscrew implant placement sites. They concluded that there were showed no significant differences in cortical bone thickness between the sexes, but significant (P\0.05) differences existed between adolescents and adults, with adult cortices significantly thicker in all areas except the infrazygomatic crest, the mandibular buccal first molar-second molar site, and the posterior palate site. But the mandibular buccal and infrazygomatic crest regions had the thickest cortical bone.

Cattaneo PM et al. 2003 [7], on Finite element analyses for cortical thickness at infra zygomatic region, A finite element analysis allows us to simulate the displacement of a molar in relation to the well-defined morphology of the maxilla. Three 3-dimensional unilateral models of a maxilla from a skull with skeletal Class I and neutral molar relationships were produced based on CT-scan data.

The maxillary first molar was localized so that the contour of the mesial root continued into the infrazygomatic crest. When the molar was loaded with occlusal forces, the stresses were transferred predominantly through the infrazygomatic crest. This changed when mesial and distal displacements of the molars were simulated. In the model with mesial molar displacement, a larger part of the bite forces were transferred through the anterior part of the maxilla, resulting in the buccal bone being loaded in compression.

In the model with distal molar displacement, the posterior part of the maxilla was deformed through compression; this resulted in higher compensatory tensile stresses in the anterior part of the maxilla and at the zygomatic arch. In other words, the functional demands placed on this region could explain its relative cortical thickness.

Hyub-Soo Lee et al. 2013[29], investigated the bone thickness of the infrazygomatic crest area by computed tomography (CT) for placement of a miniplate as skeletal anchorage for maxillary protraction in skeletal Class III children. The bone thickness of the infrazygomatic crest area was measured at 35 locations on the right and left sides, perpendicular to the bone surface. Results showed that the bone was thickest (5.0 mm) in the upper zygomatic bone and thinnest (1.1 mm) in the anterior wall of the maxillary sinus.

Generally, there was a tendency for the bone to be thicker at the superior and lateral area of the zygomatic process of the maxilla. There was no clinically significant difference in bone thickness between the right and left sides; however, it was thicker in male than in female subjects.

They concluded that in the infrazygomatic crest area, the superior and lateral area of the zygomatic process of the maxilla had the most appropriate thickness for placement of a miniplate in growing skeletal Class III children with a retruded maxilla.

W. Liou et al. 2007[40]**,** to derive clinical implications and guidance for inserting miniscrews in the IZ crest without injuring the mesiobuccal root of the maxillary first molar they measured the thickness of the infrazygomatic (IZ) crest above the maxillary first molar at different angles and positions to the maxillary occlusal plane.

The results showed that the IZ crest thickness above the maxillary first molar ranged from 5.2 +/- 1.1 mm to 8.8+/- 2.3 mm, measured at 40° to 75° to the maxillary occlusal plane and 13 to 17 mm above the maxillary occlusal plane.

They concluded that Bone thickness of the IZ crest above the maxillary first molar is 5 to 9 mm, when it is measured at 40° to 75° to the maxillary occlusal plane and 13 to 17 mm above the maxillary occlusal plane. By adopting 6 mm as the minimum IZ crest thickness for sustaining a miniscrew well throughout treatment and avoiding bone stripping, injury to the mesiobuccal root of the maxillary first molar, and alveolar/ buccal mucosa irritation.

The clinical implication for miniscrew insertion in the IZ crest of adults is 14 to 16 mm above the maxillary occlusal plane and the maxillary first molar, and at an angle of 55° to 70° to the maxillary occlusal plane.

Yi-Jyun Chen et al. 2010[80], evaluated the hard- and soft-tissue thicknesses of TAD insertion sites and the perforation ratio with different lengths of TADs using cone beam volumetric computed tomography (CBCT) in order to increase the success rate of (TADs) and not to cause root injury or soft-tissue inflammation.

The results showed that the average bone depth of the IZ crest in this study was 5.89 mm; the bone depth of the IZ crest in the male group was longer than 6 mm, but not that in the female group (not statistically significant). It was supposed that the variation in IZ crest thickness might be due to variations in the maxillary sinus among individuals.

Flavio Uribe et al. 2015[75], conducted a pilot study to evaluate the failure rates of mini-implants placed in the infrazygomatic region and to evaluate factors that affect their stability.

A retrospective cohort study of 30 consecutive patients (55 mini-implants) who had infrazygomatic mini-implants at a University Clinic were evaluated for failure rates. Patient, mini-implant, orthodontic, surgical, and mini-implant maintenance factors were evaluated for association to failure rates.

A 21.8 % failure rate of mini-implants placed in the infazygomatic region was observed. They concluded that this failure rate is slightly higher than that reported for mini-implants placed interradicularly and patient, mini-implant, orthodontic, surgical, and mini-implant maintenance factors were not predictive of failure rates.

Haibo Liu et al. 2017 [41], assessed the anatomic structure of the buccal alveolar bone in the infrazygomatic crest region with cone-beam computed tomography to locate safe zones for miniscrews in maxillary dentition distalization.

The buccal alveolar bone was analyzed in 3 regions of 60 patients (A) between the maxillary second premolar and first molar (U5-U6), (B) between the mesiodistal roots of the first molar (U6), and (C) between the maxillary first and second molars (U6-U7). Alveolar bone thickness at the buccal side of the roots and the interradicular space at the buccal side of the roots were measured at the planes of 5, 7, 9, and 11 mm apically from the alveolar crest to the maxillary sinus floor. The buccal bone height was measured from the alveolar crest edge to the sinus floor.

The results of the study was that the buccal alveolar bone was thicker in the U6-U7 region than in the U6 and U5-U6 regions. The buccal alveolar bone thickness tended to get thicker from the alveolar crest to the sinus floor. The thickest buccal alveolar bone of 4.07 mm was observed at the plane of 11 mm of the U6-U7 region.

The percentages for the height of bone from the crest edge to the sinus floor were smaller than 10 mm at the regions of U5-U6, U6, and U6-U7: 38%, 52%, and 43%, respectively. The interradicular space was smallest in the U6 region and largest in the U5-U6 region. They concluded that The region between the maxillary first and second molars (U6-U7) should be the first choice for a minisrew implanted in the buccal alveolar bone in the infrazygomatic crest region for distalization of the entire maxillary dentition.

Materials and Methods

MATERIALS AND METHODS

The present in-vitro study was carried out in the Department of Orthodontics and dentofacial Orthopedics, Ragas Dental College and Hospitals, Chennai.

The cone beam computed tomography **(Digital Kodak 9500 cone beam tomography scan, France)** images of 40 subjects irrespective of gender, who reported to the Department of Orthodontics and Dentofacial Orthopedics at Ragas Dental College and Hospital were analyzed.

Inclusion criteria

- The CBCTs which were taken as a pretreatment record for subjects with temperomandibular joint problems, facial asymmetries, patients with ectopically erupting teeth. Out of which 40 CBCTs were randomly selected from the database available in our department.

Exclusion criteria

- Subjects who had already undergone orthodontic treatment or undergoing current orthodontic treatment.
- Subjects with noticeable periodontal disease.
- Subjects with previous history of trauma.
- Subjects with the history of extraction of molars.

The CBCT images which were stored in **DICOM** format were analyzed using **Dolphin software (version 11.8).** For all scans, the minimum field of view used was 11 cm, and scan time ranged from 8.9 to 20 seconds with a resolution of 0.25 to 0.30 mm. A fully reconstructed three-dimensional image with sagittal, coronal and axial planes of the maxilla was generated and the following measurements were taken on right and left sides to be computed:

The planes selected for cortical bone measurements from maxillary first molar to maxillary second molar are:

- Mesial of maxillary first molar (6M),
- Middle of the crown through the furcation area of the maxillary first molar (6Middle).
- Interradicular bone/interdental region between the maxillary first and second molars (6-7IR).
- Middle of the crown through the furcation area of the maxillary second molar (7Middle).
- Distal of the maxillary second molar (7D)

The cortical bone thickness was measured at heights of 8mm, 10mm, 12mm and 14mm from the cemento enamel junction(CEJ).

Reference lines

- The horizontal reference line - the line passing through the cemento-enamel junction of both the right and left molars.
- The vertical reference line - the line parallel to the long axis of the molars .

The cortical bone thickness was measured from the cemento enamel junction towards the maxillary sinus floor at various heights of 8 mm, 10 mm, 12 mm and 14 mm along the mesial of upper first molar, middle of the crown through the furcation area of the maxillary first molar (6Middle), interradicular bone/interdental region between the maxillary first and second molars (6-7IR), middle of the crown through the furcation area of the maxillary second molar (7Middle), distal of the maxillary second molar (7D).

HYPOTHESIS: No difference in bone thickness in the infrazygomatic region of 1st and 2nd molars.

STATISTICAL ANALYSIS

The following statistical procedures were carried out :

1. Data compilation and presentation
2. Statistical analysis

I Data compilation and presentation:

Data obtained were systematically compiled in Microsoft Excel spread sheet . The dataset was subdivided and distributed meaningfully and presented as graphs and tables.

II. STATISTICAL ANALYSIS :

Statistical analysis were performed using Statistical Package for Social Sciences Software (SPSS version 22.0, IBM). Data comparison was done by applying specific statistical tests to find out the statistical significance of the obtained results. Depending on the nature of the data, statistical tests were chosen . p value of 0.05 was considered to be significant.

Normality was checked using Kolmogrov Smirnov test. All the data were found to be not normal in distribution. Hence, non-parametric test was used. The inter group comparison between 5 different slices were done using Kruskal Wallis-11 test.

Figures

FIGURE 1 : CBCT IMAGE OF A SUBJECT

FIGURE 2 : SAGITTAL VIEW CBCT SLICE

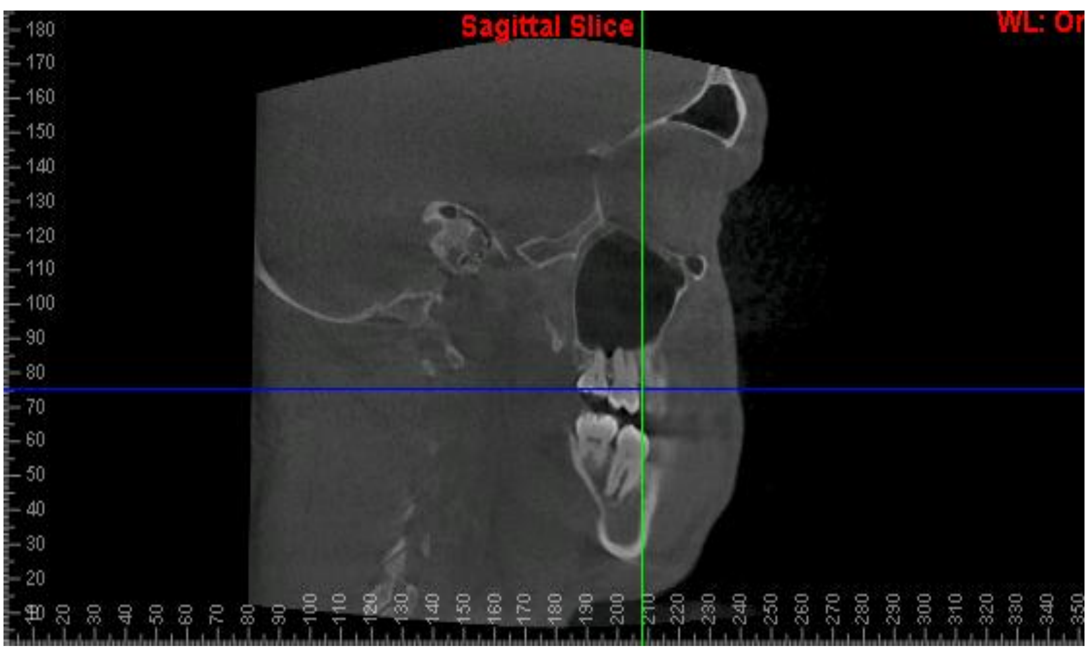


FIGURE 3: CORONAL VIEW CBCT SLICE

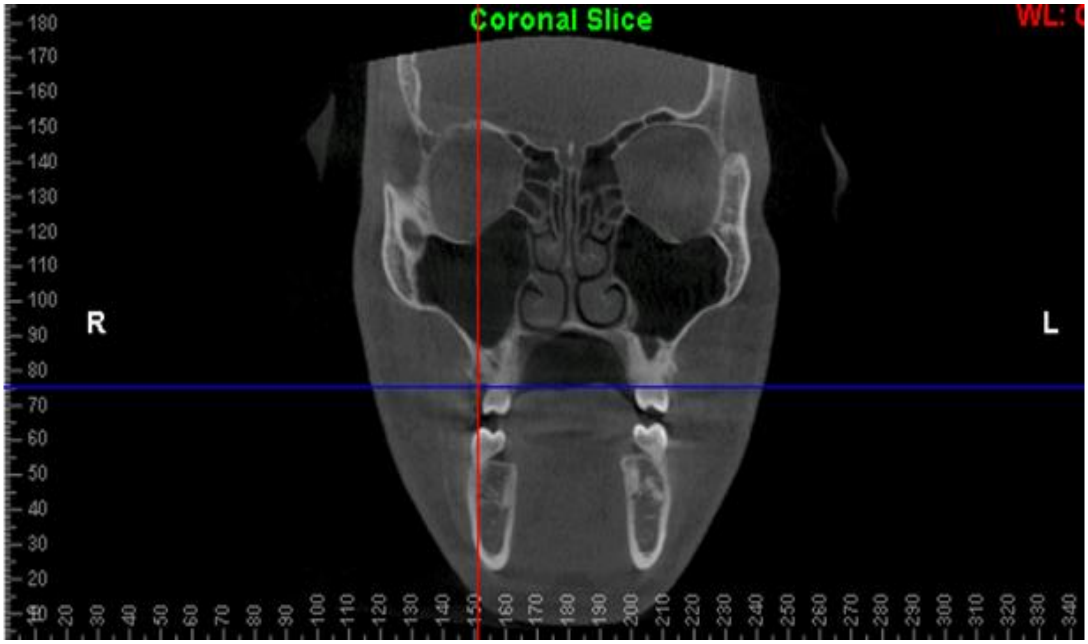


FIGURE 4 : AXIAL VIEW CBCT SLICE

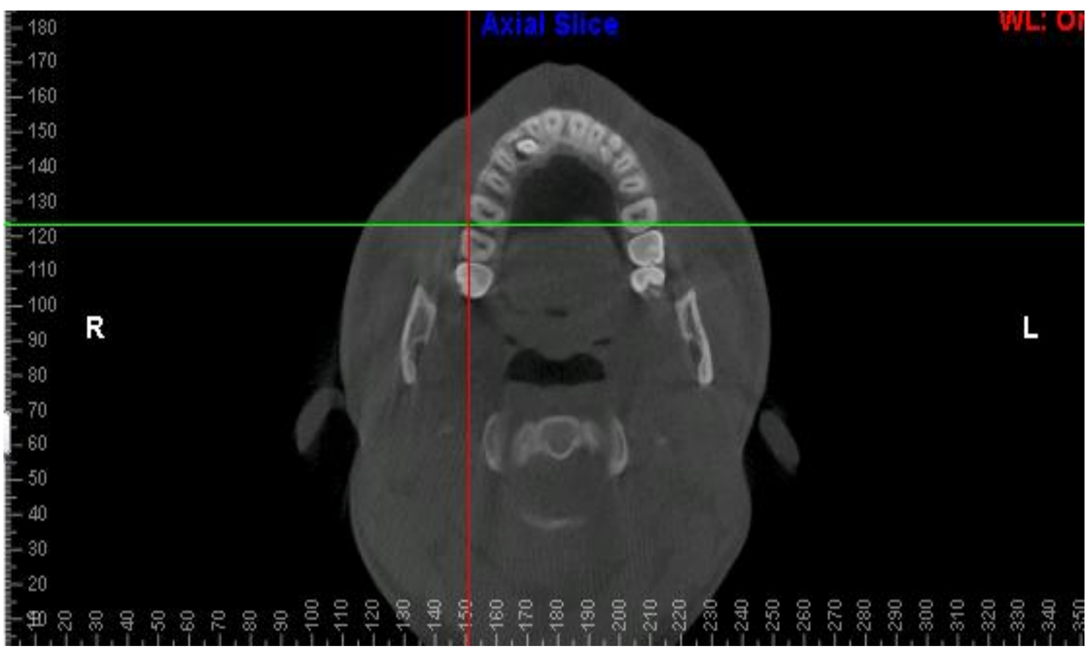


FIGURE 5: MESIAL OF MAXILLARY FIRST MOLAR – 6 MESIAL

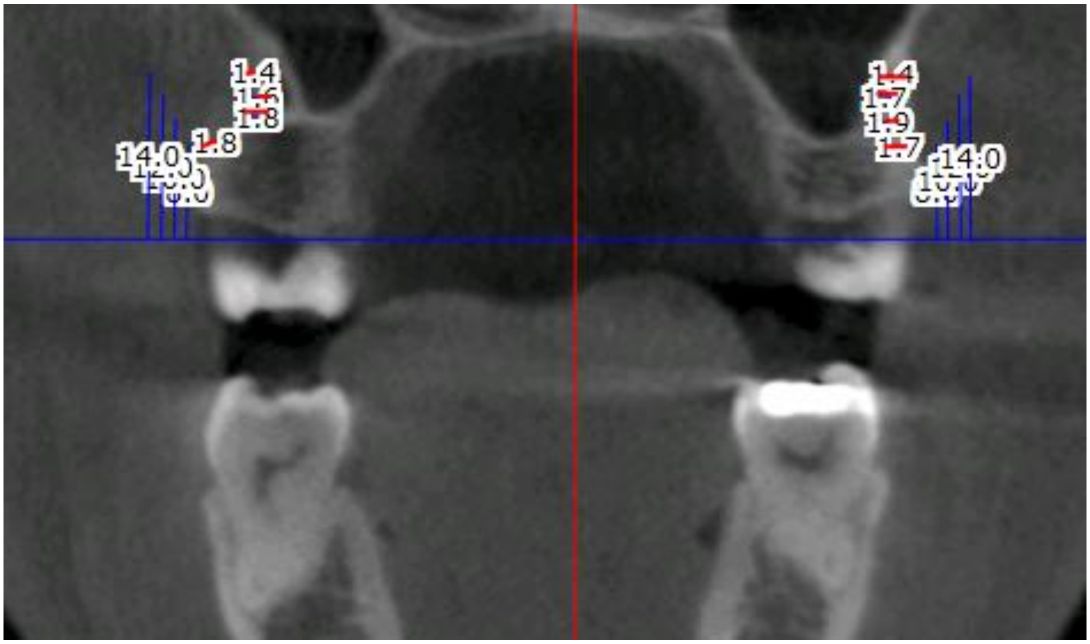


FIGURE 6: MIDDLE OF MAXILLARY FIRST MOLAR – 6 MIDDLE

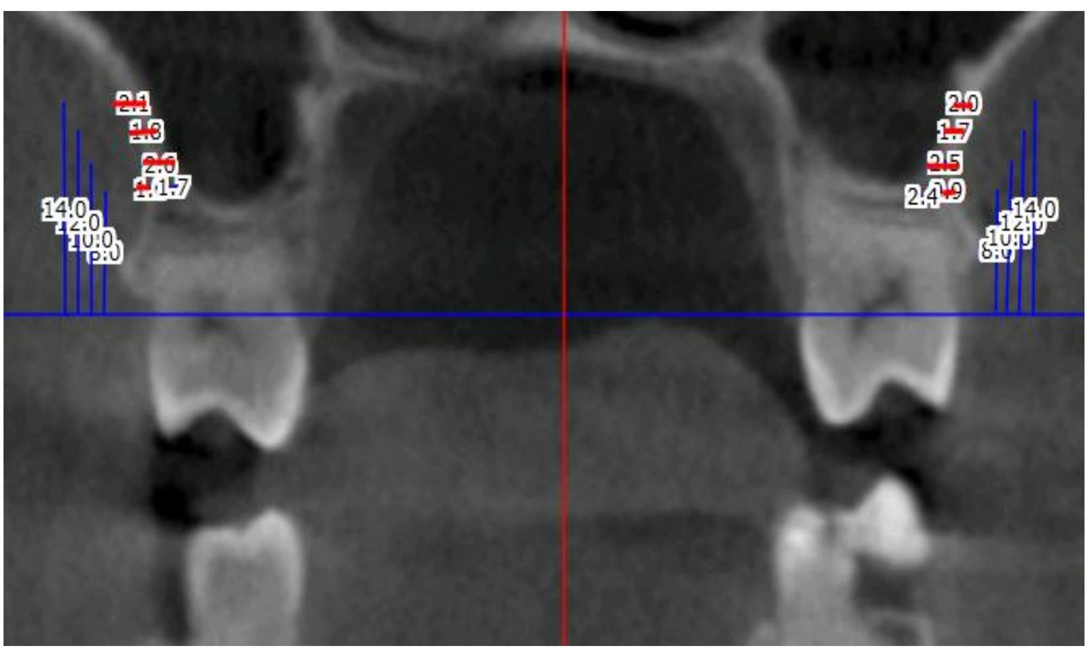


FIGURE 7: INTERDENTAL REGION BETWEEN MAXILLARY FIRST MOLAR AND SECOND MOLAR - 6-7 INTERDENTAL

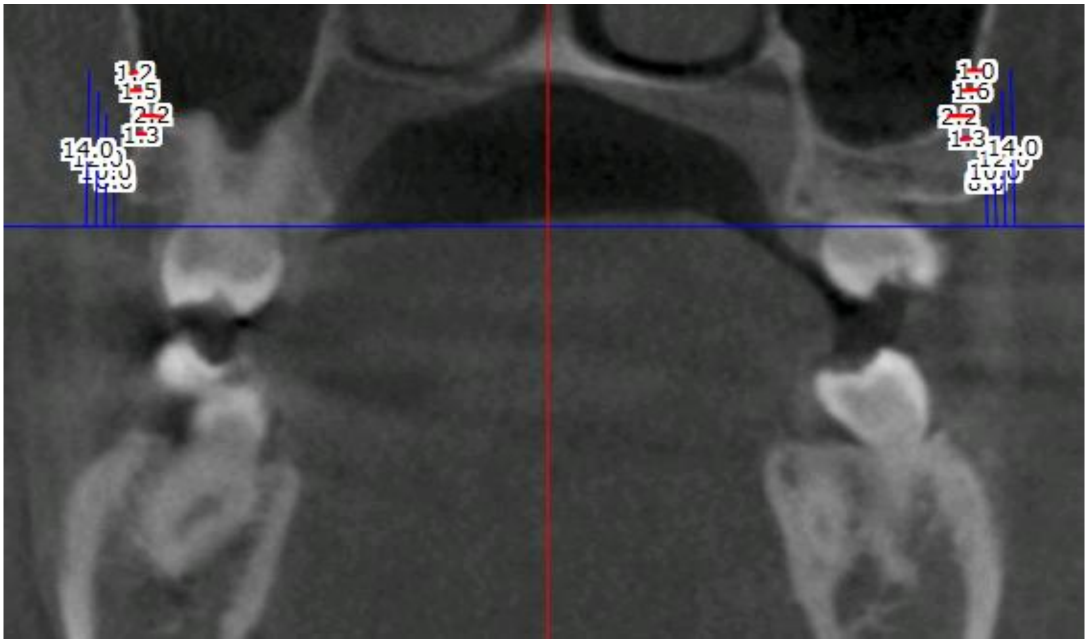


FIGURE 8: MIDDLE OF MAXILLARY SECOND MOLAR – 7 MIDDLE

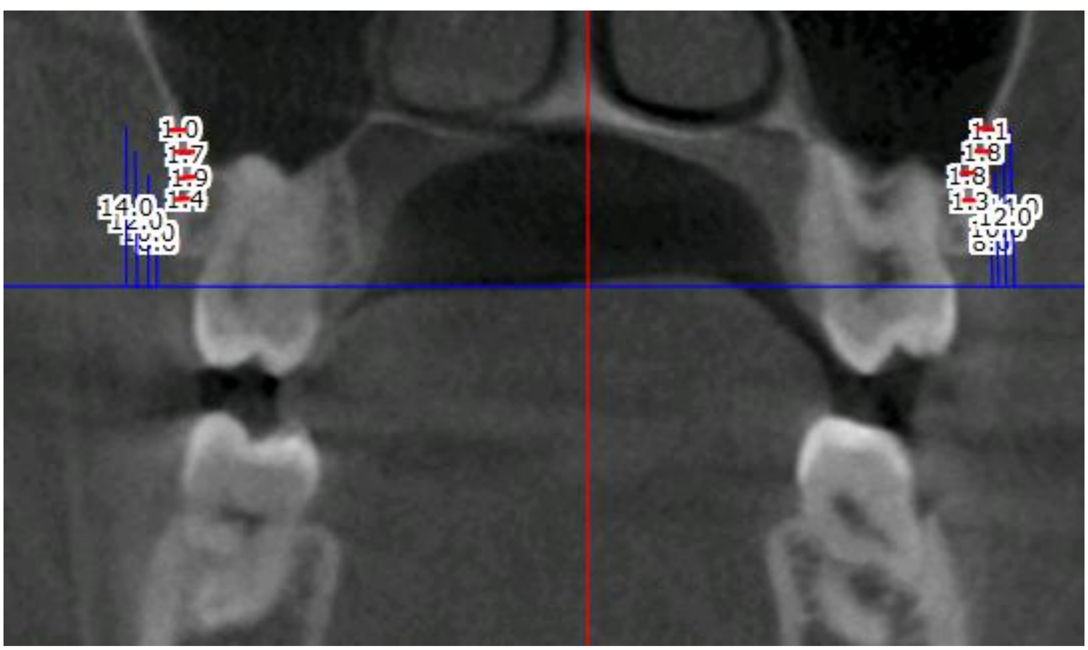
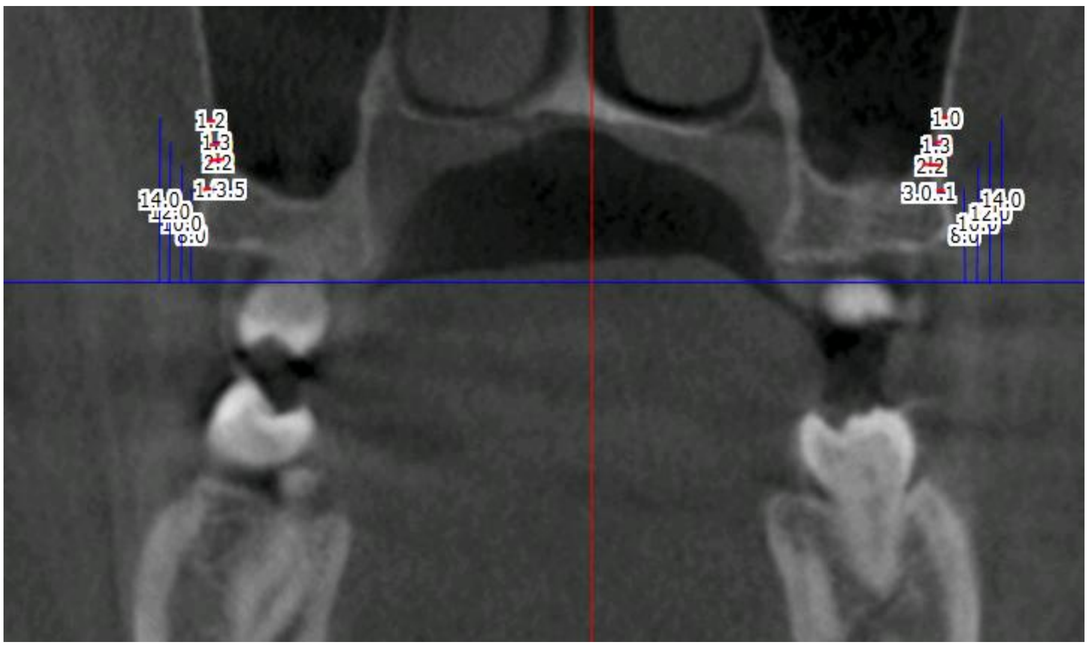


FIGURE 9: DISTAL OF MAXILLARY SECOND MOLAR – 7 DISTAL



Results

RESULTS

This in-vitro study was performed to evaluate the thickness of cortical bone in the infra zygomatic region using bone mapping – a cone beam computed tomography study. The results are based on bone mapping done on 40 CBCTs in the range of 18 to 30 years of age **(Fig 1).**

All the CBCTs were obtained from the patients who reported seeking treatment to the Department of Orthodontics and Dentofacial Orthopaedics at Ragas Dental College and Hospital, Uthandi, Chennai, India .

Descriptive statistics was carried out statistically to determine the cortical bone thickness in the study group,

The results are discussed under the following headings:

1. Comparison of cortical bone thickness in the infra zygomatic region

along 5 different slices (anteroposteriorly).

2.Comparison of cortical bone thickness in the infra zygomatic region **at 4 various heights (vertically)**

<u>Comparison of cortical bone thickness in the infra-zygomatic regions along 5 different slices (anteroposteriorly) :</u>

The mean and the standard deviation of cortical bone thickness at 5 different slices were compared **(Table 1) .**

The cortical bone thickness among 5 different slices, at 4 different heights are highly statistically significant (p =0.01). The cortical bone thickness gradually increased from mesial of maxillary first molar (6M) towards the interdental region between the maxillary first and second molar (6-7 ID) . This gradually decreased from middle of second molar (7 Middle) towards the distal of second molar (7D) . The cortical bone thickness tended to get thicker from cemento-enamel junction towards the maxillary sinus floor along the heights of 8mm, 10mm & 12mm and started to decrease towards 14mm **(Figure: 11).**

The interdental region between the maxillary first and second molar (6-7ID) had the thickest cortical bone of 2.36mm at the height of 12mm from the cemento-enamel junction. The distal of second molar (7D) had the thinnest bone of 0.81mm at the height of 8mm **(Table 1&2)**.

The mesial of first molar (6M) had the thickest cortical bone of 2.25mm at the height of 12mm from the cemento-enamel junction and thinnest of at the height of 8mm **(Figure :12) (Table 1).**

The middle of first molar (6Middle) had the thickest cortical bone of 2.35mm at the height of 12mm from the cemento-enamel junction and thinnest of at the height of 8mm **(Figure 13) (Table 1).**

The interdental region between the maxillary first and second molar (6-7 ID) had the thickest cortical bone of 2.36mm at the height of 12mm from the cemento-enamel junction and thinnest at the height of 8mm **(Figure 14) (Table 1).**

The middle of second molar (7Middle) had the thickest cortical bone of 1.77mm at the 12mm from the cemento-enamel junction and thinnest at the height of 8mm **(Figure 15) (Table 1).**

The distal of second molar (7D) had the thickest cortical bone of 1.55mm at the 14mm from the cemento-enamel junction and the thinnest at the height of 8mm **(Figure 16) (Table 1).**

2. <u>Comparison of cortical bone thickness in the infra zygomatic regions at 4 various heights.</u>

The mean cortical bone thickness was more at the height of 12mm in all 5 slices except for the distal of second molars (7D), which was at the height of 14mm **(Table 2).**

At the height of 8mm, the cortical bone thickness was more in the region mesial to first molar (6M) which was 1.29mm **(Figure 17) (Table 2).**

At the height of 10mm, the cortical bone thickness was more in the interdental region between the maxillary first and second molar (6-7 ID) which was 1.8mm **(Figure 18) (Table 2).**

At the height of 12mm, the cortical bone thickness was more in the interdental region between the maxillary first and second molar (6-7 ID) and the middle of maxillary first molar (6Middle) which was 2.36mm and 2.35mm respectively **(Figure 19) (Table 2).**

At the height of 14mm, the cortical bone thickness was more in the region mesial to first molar (6M) of 2.21mm **(Figure 20) (Table 2).**

Tables & Graphs

Table 1: **Mean values for each of the heights at various slices.**

SLICES	**HEIGHTS**			
	8mm	**10mm**	**12mm**	**14mm**
6M	1.29	1.70	**2.25**	2.21
6 Middle	1.26	1.74	**2.35**	2.18
6-7 ID	1.26	1.80	**2.36**	1.97
7Middle	1.10	1.39	**1.77**	1.70
7D	0.81	1.09	1.43	**1.55**
p value	**0.01**	**0.01**	**0.01**	**0.01**

(6M)-*mesial of upper 1st molar,* (6 Middle) - *middle of upper 1st molar,* (6-7 ID) - *interdental region between upper 1st and 2nd molar,* (7Middle) - *middle of upper 2nd molar,* (7D) - *distal of upper 2nd molar.*

Table 2: Mean values for each of the slices at various heights.

HEIGHTS	SLICES				
	6M	**6 Middle**	**6-7IR**	**7 Middle**	**7D**
8mm	**1.29**	1.26	1.26	1.10	0.81
10mm	1.70	1.74	**1.80**	1.39	1.09
12mm	2.25	2.35	**2.36**	1.77	1.43
14mm	**2.21**	2.18	1.97	1.70	1.55
p value	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

(6M)-*mesial of upper 1st molar*, (6 Middle) - *middle of upper 1st molar*, (6-7 ID) - *interdental region between upper 1st and 2nd molar*, (7Middle) - *middle of upper 2nd molar*, (7D) - *distal of upper 2nd molar*.

FIGURE 10: Total number of patients (n) = 40 , with 21 males and 19 females.

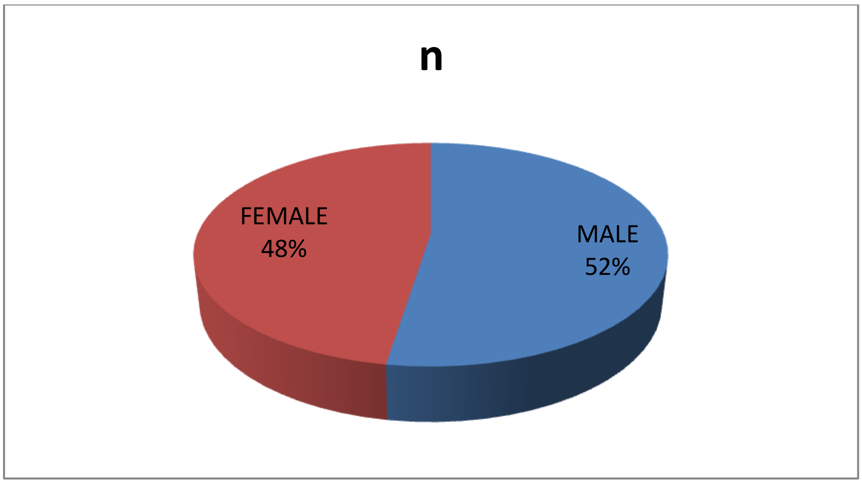
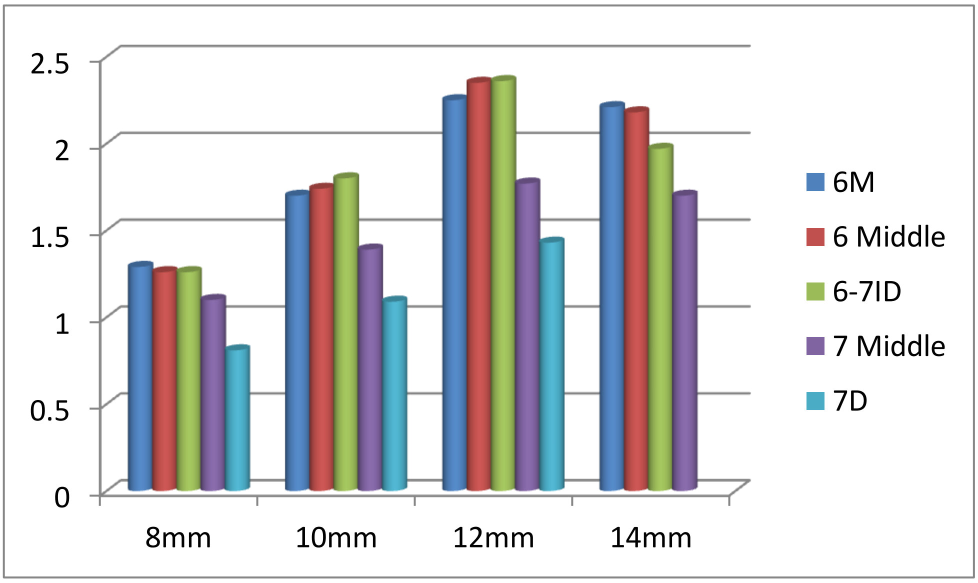


FIGURE 11: Mean values for each of the heights at various slices.



(6M)-*mesial of upper 1st molar*, (6 Middle) - *middle of upper 1st molar*, (6-7 ID)- *interdental region between upper 1st and 2nd molar*, (7Middle)- *middle of upper 2nd molar*, (7D)- *distal of upper 2nd molar*.

FIGURE 12. Cortical bone thickness mesial to 1st molar (6M) along 8mm, 10mm, 12mm, 14mm.

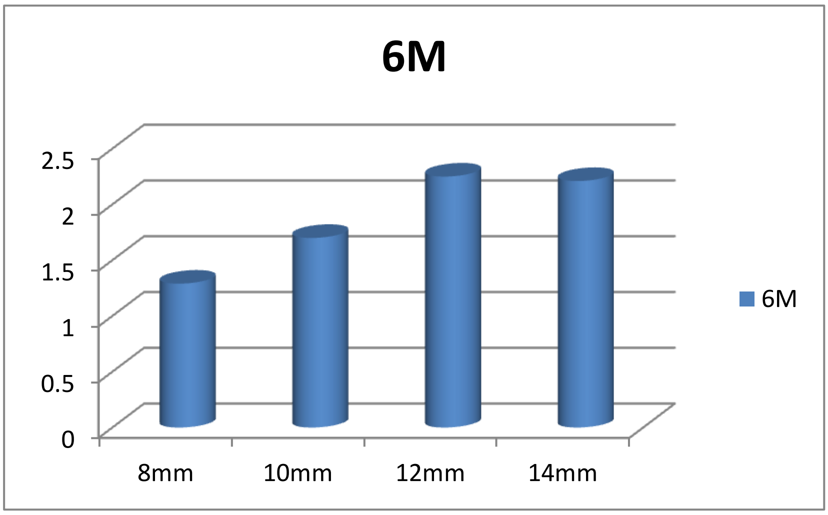


FIGURE 13. Cortical bone thickness middle to the 1st molar (6 Middle) along 8mm, 10mm, 12mm, 14mm.

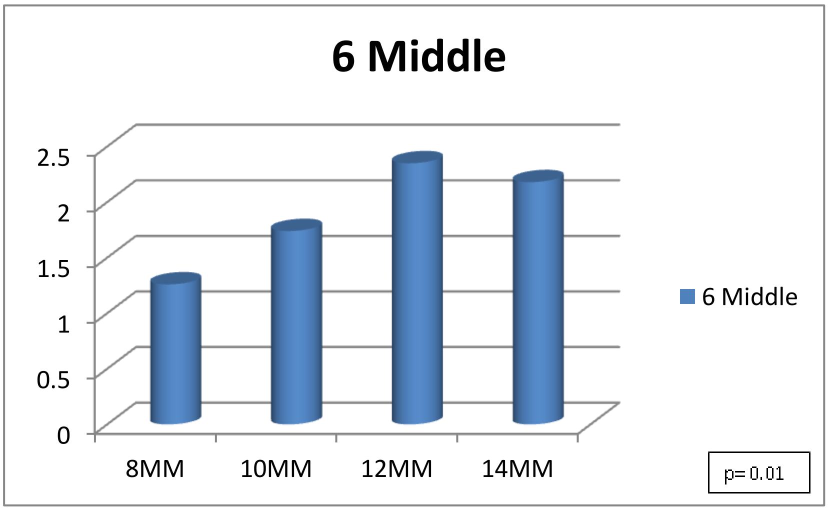


FIGURE 14. Cortical bone thickness in the interdental region between the maxillary first and second molar (6-7 ID) along 8mm, 10mm, 12mm, 14mm.

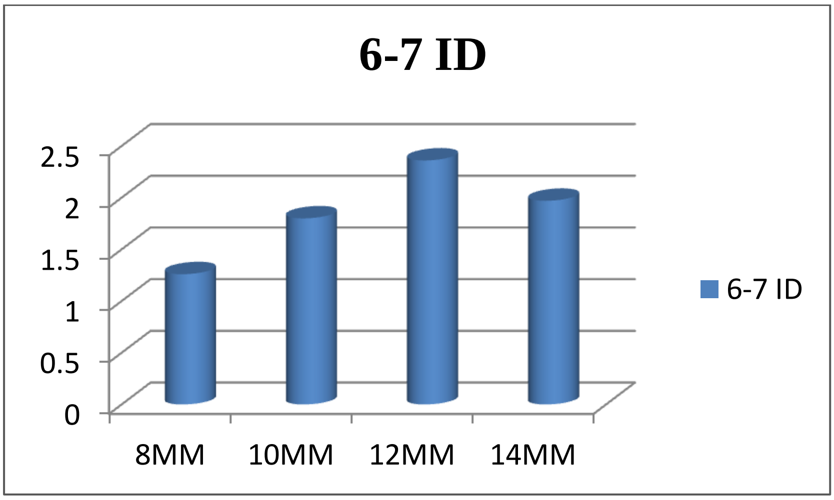


FIGURE 15. Cortical bone thickness middle of the 2nd molar (7 Middle) along 8mm, 10mm, 12mm, 14mm.

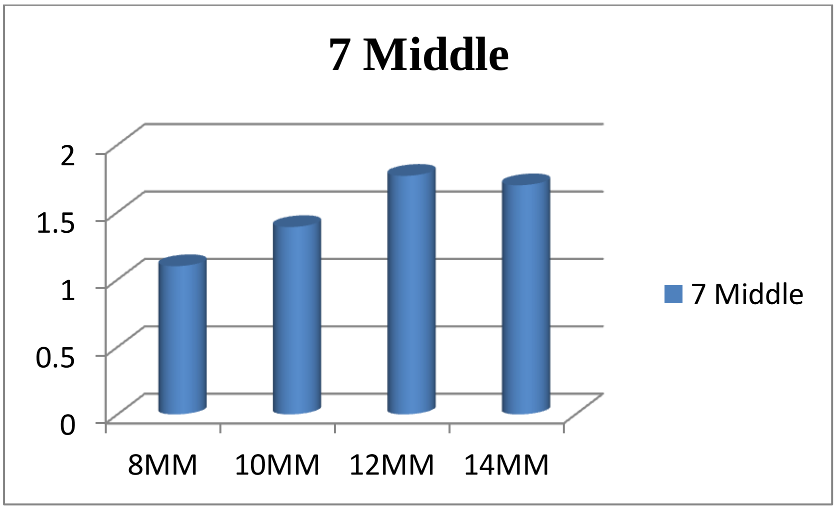


FIGURE 16. Cortical bone thickness distal to the 2^{nd} molar (7D)along 8mm, 10mm, 12mm, 14mm.

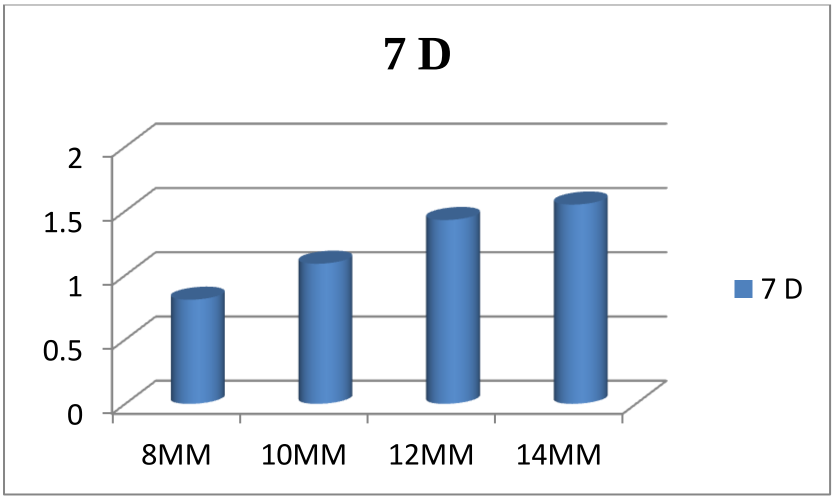


FIGURE 17. Cortical bone thickness at 8mm along all the 5 regions.

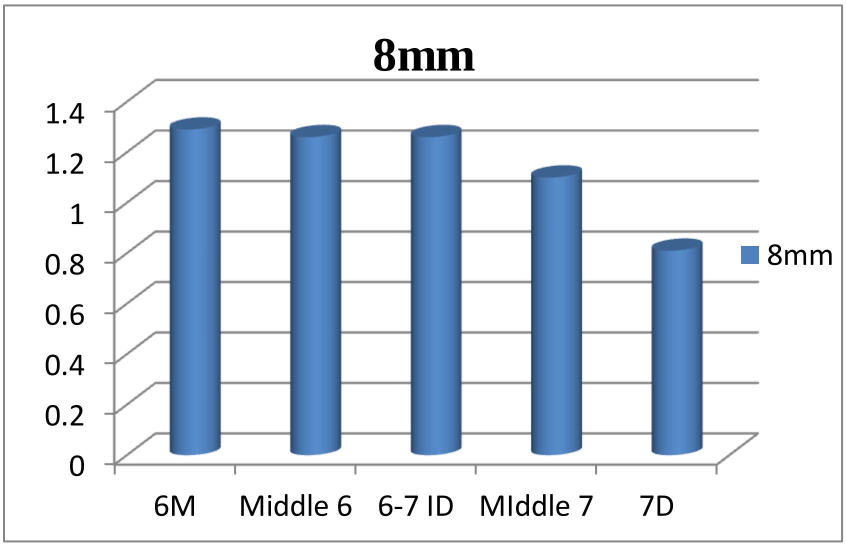


FIGURE 18. Cortical bone thickness at 10mm along all the 5 regions.

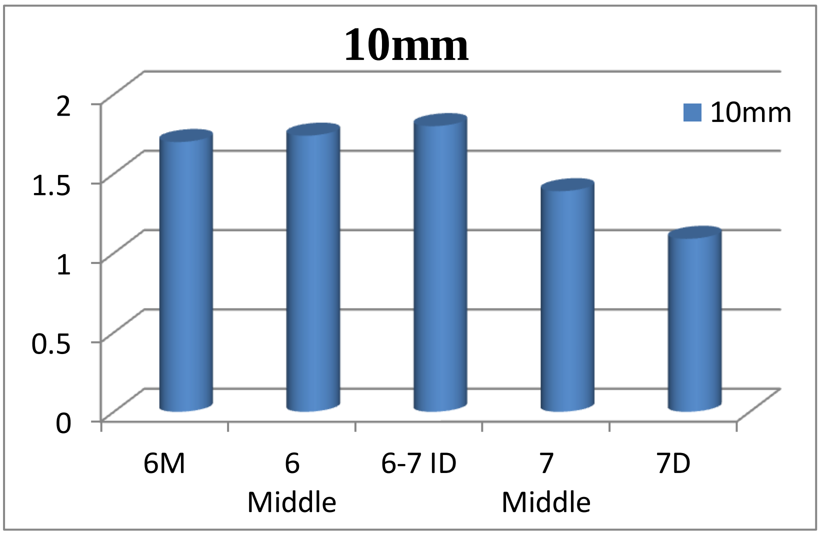


FIGURE 19. Cortical bone thickness at 12mm along all the 5 regions.

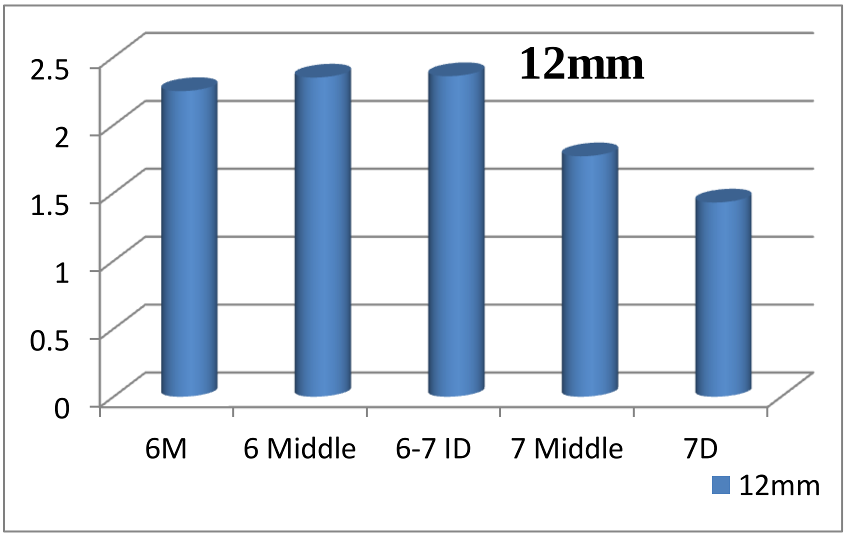
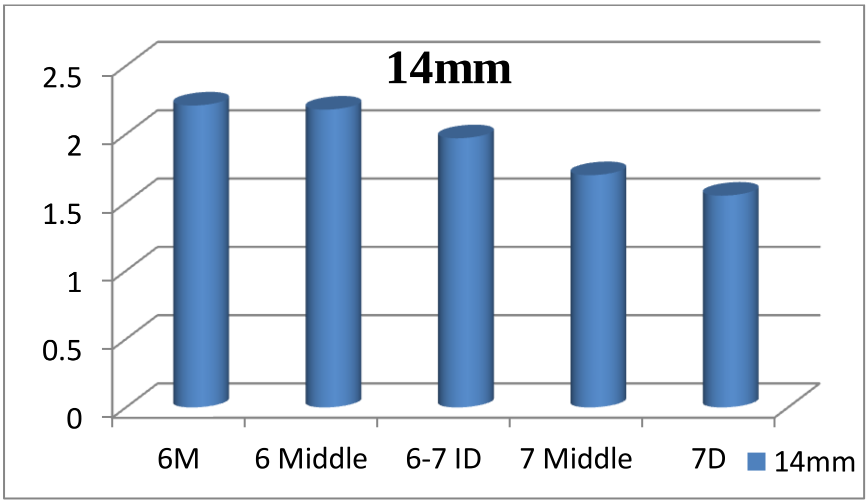


FIGURE 20. Cortical bone thickness at 14mm along all the 5 regions



Discussion

DISCUSSION

The aim of our study was to analyze and measure the buccal cortical bone thickness in the infrazygomatic crest (IZC) along the maxillary first and second molar regions at four different heights from the cementoenamel junction (vertically) and along five different slices taken from the mesial of maxillary first molar to distal of maxillary second molar (horizontally) to determine safe zones for ideal placement of temporary anchorage devices (TADs). This is to obtain good primary stability and for the distalization of maxillary dentition without affecting periodontal health.

Prevalence of malocclusion traits show a definite ethnic and geographical variation. Worldwide data shows it to be more prevalent in whites than in blacks, more in developed countries than developing countries and more in urban as compared to rural population[65].

Indian population is comprised of multitude of races and ethinicity, there is a definite racial and geographical variation between the northern and southern parts of India.

A literature review by **Sandhu[65] ,** stated that the prevalence of Class II malocclusion in Delhi and Haryana (North India) is much higher (10-15%) when compared to Bangalore and Thiruvananthapuram (South India) where it is only around 5%. In addition, the prevalence of bimaxillary protrusion is more among south Indian population.

Class I malocclusion is the most prevalent malocclusion in India followed by class II and class III which is different from Chinese and Korean population, which is mostly class III malocclusion[37].

The prevalence of type of malocclusion in an ethnic chinese population was studied by **Lew KK[37]** and found to have a high incidence of Class III malocclusion when compared with caucasians.

Various authors have evaluated, safe zones for miniscrew placement in interradicular spaces, using CBCT. To the best of our knowledge, an evaluation of the anatomic structure in buccal cortical bone at the infrazygomatic region, three dimensionally has not been done in our population. Hence we set out to create a standard or normative data among our population. This study can be considered a pilot study for the future studies on this domain.

CORTICAL BONE THICKNESS

The thickness of available cortical bone is of vital importance for stability of mini-implants placed, and one of the common reason for the failure of mini-implant is insufficient bone. The implant stability here depends on mechanical interdigitation of bone and implant rather than osseointegration. Therefore, bone quantity seems to be the major factor in the stability of miniscrews.

Kim[34] stated that the stability of miniscrew implants depends on the quality (bone density) and quantity (bone volume) of the cortical bone. The main objective of an orthodontic screw is to gain maximum retention by placing the screw in an area with the thinnest soft tissue and the thickest cortical bone**.**

Numerous anatomical sites for placement of miniscrews have been discussed by **Park**[60]**,** where he inserted micro-implants of 1.2 mm in diameter into the alveolar bone between the roots of the posterior teeth to change the direction of the applied force towards increasing the horizontal component of the force.

He did a CT (Computed Tomography) study to provide safe locations for clinicians to place mini-implants where he observed that the inter-radicular space between the second premolar and first molar root in the upper arch and inter-radicular space between the first molar and the second molar root in the lower arch were suitable sites.

Later, **Poggio**[62] provided an anatomical map for placing miniscrews in the interradicular area in both maxilla and mandible and also came up with the desired morphological features that an ideal miniscrew should possess, so that, it could be safely placed in inter-radicular areas.

Wherein studies by **Kuroda**[36] stated that the major problem encountered with placing TADs inter-radicularly, is the increased risk of root approximation which can sometimes impede tooth movement, in a situation wherein a tooth has not moved a sufficient distance to an expected position and is already touching the TAD. This situation that could never occur if they were placed in the extra-alveolar region, because of the above reason it is preferable to place mini-implants in the portion above the alveolar process whenever possible.

The extra-alveolar sites available for placement of TADs include incisive fossa, premaxillary region, midpalatal region, and symphysis, canine fossa, infrazygomatic (IZ) crest, anterior external oblique ridge (AEOR), retromolar area, and sublingual fossa.

Chris Chang[13] enumerated many advantages of extra-alveolar sites over inter-radicular (I-R) sites, which are, less risk of tooth root damage, more bone at the site of placement which permits a larger screw diameter (2mm), no interference with the path of tooth movement, adequate anchorage for enmasse retraction, much lower failure rates and the need for fewer TADs for comprehensive treatment of severe malocclusions.

In addition to this, **Melsen and Verna**[47] stated other advantages of placing TADs in extra alveolar sites can provide easier and wider applications in tooth movement, such as intrusion of posterior segment, retraction of anterior teeth, molar uprighting, distalisation of maxillary and mandibular molars.

Studies by cortical bone thickness and root proximity in maxillary inter-radicular sites by **Sawada**[67] stated that a cortical bone thickness of atleast 1 mm is necessary to achieve mini-implant stability. On measuring the cortical bone thickness, the superior part of the alveolar process tended to be thicker than the inferior part.

On evaluating cortical bone thickness of the upper jaw, **Cassetta**[6] found that the buccal cortical bone was thinner than the palatal cortical bone. There is an increase of thickness and density from crest to base of alveolar bone. Studies by **Baumgaertel**[4] showed that the buccal cortical bone thickness decreased at the 4-mm mark before it increased again at the 6-mm mark.

These findings agree with the study of **Kim**[34] when they investigated the buccal interproximal areas of the maxilla, found that, the ‘‘cortical bone was thickest closest to and farthest from the CEJ and thinnest in the middle.’’ This demonstrates that, to maximize cortical bone anchorage in the maxillary buccal sextants, the mini-implant should be placed more than 4 mm apically from the alveolar crest, which means that when placing the mini-implants in the maxillary buccal sextants, it has to be placed close to the mucogingival junction or perhaps even in mucosa.

But as we go apically, the presence of the nasal cavity and maxillary sinus perforations might pose a major setback. **Ardekian**[1]**,** reported that perforations less than 2 mm of the maxillary sinus can heal by themselves and rarely caused complications.

Apart from this the anatomical limitations imposed by the transition from the attached gingiva to the alveolar mucosa needs to be considered. One of the potential problem of placing TADs in extra-alveolar bony sites is that, if placed extra-alveolarly, the TAD will lay in mobile alveolar mucosa, possibly causing problems.

Shih–Jung Cheng[10] stated that, TAD when placed in some extra-alveolar bony sites, due to the lack of adequate keratinized mucosa may potentially cause mucosal inflammation, food impaction and discomfort. **Costa**[15] proposed a way to prevent this, he suggested us to place the TADs in the mobile mucosa, that is, cover the screw head beneath the mucosa by incorporating a transmucosal attachment so that orthodontic attachment lay superior to the soft tissues and this attachment acts as an extension for force application.

To overcome the above disadvantage of soft tissue coverage, **Yi-Jyun Chen**[80] proposed to use TADs with a longer smooth neck design in the presence of thicker soft tissue.

Sebastian and Terri[3]**,** called the movable mucosa above the mucogingival junction as a *"zone of opportunity."* Mucosa becomes firmly attached to the periosteum at the muco gingival junction, and there is virtually no mobility, relative to underlying bone, so movable mucosa is an ideal site for Inter-radicular miniimplant or miniscrew insertion.

Various studies (by **Baumgaertel**[3], **Motoyoshi**[55], **Wilmes**[78], **Kuroda**[36]**)** state that the cortical bone thickness increases in the apical direction and the movable mucosa apical to the mucogingival junction offers TAD sites with more space between the conical dental roots because they usually diverge in an apical direction.

Chris chang[13] conducted a study to compare six-month failure rates for infra-zygomatic crest (IZC) bone screws inserted into movable mucosa (MM) or attached gingiva (AG), with the hypothesis that MM would have a higher failure rate than AG. The study concluded that there was no statistically significant difference for sites covered with movable mucosa or attached gingiva.

INFRAZYGOMATIC CREST:

Of all extra-alveolar sites, our study of interest is the infra-zygomatic region. The infrazygomatic (IZ) crest is an extra-alveolar placement site in the maxilla for orthodontic miniscrews or miniplates. It has been successfully used to provide skeletal anchorage for maxillary canine retraction, anterior retraction, en-masse anterior retraction, and intrusion of the maxillary posterior teeth.

The infrazygomatic crest space is a rectangular osseous volume that is limited by certain distinct borders. The buccal border of the infrazygomatic crest space is represented by the course of the outer surface of the zygomatic process of the maxilla and the most apical regions of the alveolar process. The medial border consist of the lingual root of the maxillary first molar, the lingual surface of the alveolar process and the surfaces of the nasal cavity.

Anatomically, the IZ crest is a thick pillar of cortical bone along the zygomatic process of the maxilla. Clinically, it is a palpable bony ridge running along the curvature between the alveolar and zygomatic processes of the maxilla. Studies of **Kanomi**[33] and **Schnelle**[69] concluded that it is between the maxillary second premolar and first molar, in younger subjects and is above the maxillary first molar in adults.

It is recommended to insert miniscrews at a height beyond the root apex, where interseptal bone is thicker and there is less chance of root injury. **Eric Liou**[40] in his study stated that the IZ crest above the maxillary first molar, was significantly thicker than the lateral wall of the maxillary sinus. The IZ crest is usually used as an insertion site for orthodontic skeletal anchorage, because of its thicker bone. He also stated that the IZ crest has 2 cortical plates—the buccal cortical plate and the sinus floor. This is anatomically advantageous as it allows for bicortical fixation and also offers a better shot at primary stability of the miniscrew.

According to **Misch and Kircos** [50] **,**the bone density of the IZ crest is greater than that of the maxillary alveolar ridge, Where the bone present were mostly porous cortical bone and dense trabecular bone rather than porous cortical and trabecular bone present in the alveolar region . (D2/D3 vs D3/D4).

. Structurally, the maxilla has relatively thin cortices that are interconnected by a network of trabeculae.

Javed [31] in his literature review stated that clinically, a poor degree of bone mineralization or limited bone resistance is observed in bones with poor densities, which are often referred to as “soft bones”. It has been shown that achieving optimum primary stability in soft bones is difficult and is also related to a higher implant failure rate for the implants placed in such bones.

In an experimental study conducted by **Niimi** [57]**,** he demonstrated the removal torque for implants in the fibula, iliac crest, and scapula of cadavers were related to cortical bone thickness, not total bone thickness and also the primary implant stability depends largely upon cortical bone thickness.

This was substanciated by another study by **Miyamoto**, demonstrated that dental implant stability in humans were greatly influenced by cortical bone thickness. Bone thickness being an important factor, **Deguchi**[19] said that a thicker bone allows a greater miniscrew biting depth, more osseous contact, and better primary stability of the miniscrew .

Clinical significance of these studies state that interdental buccal cortical bone thickness appears to vary according to distinctive patterns. Studies by **Deguchi[19],** said that shortcomings in cortical bone thickness can be compensated for by variations of mini-implant angulation or perhaps implant design (cylindrical vs conical shank).

It is not primarily the ratio of cortical bone to trabecular bone that influences implant stability, but it is the absolute amount of dense cortical bone. **Holmes,** in his investigations, showed that cortical bone has a higher modulus of elasticity than trabecular bone. It is stronger and more resistant to deformation, and will also bear more load in clinical situations than trabecular bone. Studies by **Roze[64],** states that the trabecular bone structure seems to play a minimal role in primary fixation but is certainly of considerable importance for peri-implant bone healing.

Failure of implants stability was directly associated with the thinner cortical bone in the posterior regions, when used as orthodontic anchorage. this was poved by **Miyawaki [52].**

Hard-tissue quality and quantity affect the success rates of TADs. **Huang[27],** stated that, TAD insertion loading strain values may exceed the level of microfractures, thus leading to screw loosening.

Recently **Sang hoon lee,** concluded that increase in cortical bone thickness correlated with the increase in bone density and the primary implant stability which correlated with the previous studies.

In order to place TADs it is important to assess the quality and quantity of bone in the proposed site of interest. This is when CT and CBCT has an important role to play, as this allows us to visualise the area of interest in all 3 planes of space, guiding us in the safe placement of TADs . While, Computed Tomography (CT) has a definite edge over Cone Beam Computed Tomography (CBCT) in terms of better assessment of bone, qualitatively and quantitatively, CBCT, on the other hand, paints sufficient picture of the dento-alveolar segments three dimensionally with much lesser radiation exposure and cost.

Ribeiro[63] in his study concluded that CBCT is a ground-breaking diagnostic method in dentistry as it provides high dimensional accuracy of the facial structures and a reliable method for quantifying the behaviour of the maxillary halves, dental tipping, bone formation at the suture in all the three planes of space, as well as alveolar bone resorption and other consequences of palatal expansion.

Shilpa Kalra[32] substantiated that, even though two dimensional intra oral radiographs seem to provide sufficient information for mini-implant placement. Only CBCT can provide an accurate three dimensional visualization of the inter-radicular space.

But the routine use of CBCT is not recommended for orthodontic mini-implant placement. However, if mini-implant placement is difficult because of complex anatomy such as an expanded sinus or alveolar bone loss, the use of CBCT data for planning may be considered. Also **Hodges**[26] proposed that CBCT scans should be ordered only when there is clear, specific, individual clinical justification.

Liu[41] conducted a study to analyze buccal alveolar bone in 3 regions of 60 patients between the maxillary second premolar and first molar, between the mesiodistal roots of the first molar, and between the maxillary first and second molars . Alveolar bone thickness at the buccal side of the roots and the inter-radicular space at the buccal side of the roots were measured at the heights of 5, 7, 9, and 11 mm apically from the alveolar crest to the maxillary sinus floor. Similarly in our study, CBCT data of 40 patients were randomly selected and the cortical bone thickness was measured along five regions from mesial of maxillary first to distal of maxillary second molars at heights of 8mm, 10mm, 12mm and 14mm apically from the cemento enamel junction.

On studying safe zones for mini-implant placement, **Poggio**[62], **Monerat**[53] and **Liu**[41] used a line passing through the alveolar crest as the horizontal reference line, wherein **Fayed**[22] in his study used cement-enamel junction as the reference line.

This is because alveolar crest could be affected by different periodontal problems and hence we used cement-enamel junction as the reference line in our study.

Statistical analysis were performed using Statistical Package for Social Sciences Software (SPSS version 22.0, IBM). The normality of the data was checked using Kolmogrov Smirnov test. All the data were found to be not normal in distribution. Hence, a non-parametric test was used. The inter group comparison between 5 different slices were done using Kruskal Wallis-11 test. The p value of 0.05 was considered to be significant.

Results of our study depicted that the cortical bone thickness was found highest along the region between upper first and second molar and between the roots of first molar at the height of 10mm and 12mm .

This correlates with the previous study by **Ono**[58]**,** where he evaluated buccal cortical bone thickness between the first premolar and first molar at vertical heights ranging from 1 to 15 mm below the alveolar crest in the maxilla and mandible in 43 adult patients using computed tomography. They found that, in maxilla, the cortical bone thickness distal to the maxillary first molar at heights of 6–15 mm was found to be thicker than that mesial to the first molar.

A recent study by **Liu**[41] had a similar result. He assessed the anatomic structure of the buccal alveolar bone in the infrazygomatic crest region with cone-beam computed tomography. There was a significant difference in the buccal alveolar bone thickness among the regions of upper second premolar and first molar, along upper first molar and between upper first molar and second molar at the same plane (P = 0.01).

He concluded that the thickest buccal alveolar bone was located in the maxillary first and second molar region above the 5-mm plane, which correlated with the results of our study.

Study conducted by **Farnsworth**[21] states otherwise, when he measured and compared cortical bone thickness in common mini-screw implant sites of 26 adults and 26 teenagers. He found out that there was no significant difference in thickness of cortical bone in the infrazygomatic crest. This differed from the results of our study.

He stated that the cortical bone was thicker between the maxillary first premolar-second premolar and second premolar-first molar sites than bone at the lateral-canine and first molar-second molar sites.

The farther from the alveolar crest, the thicker the cortical bone tended to be, which is similar to the results of our study where the cortical bone thickness increased with the increase in the vertical heights. But, our study showed a decrease in the thickness at the heights of 14mm from cementoenamel junction , along the lateral walls of maxillary sinus.

Also our study results showed decreased cortical bone thickness present distal to maxillary second molar (7D). This is consistent with a study by **Deguchi[19],** when he quantitatively evaluated the cortical bone thickness in various locations in the maxilla and the mandible. He found that there was significantly less buccal cortical bone present distal to the maxillary second molar region compared with the mesial and distal areas of the first molars.

Results of our study shows increase in the cortical bone thickness mesial of maxillary first molar at the heights of 8mm and 14mm.

This is consistent with the study conducted by **Schnelle[69]** who did a study to radiographically evaluate the availability of bone for placement of miniscrews. The results stated that the bone stock for placement of screws was found to exist along mesial to maxillary first molars where inadequate bone was located more than halfway down the root length, which is likely to be covered by movable mucosa.

Therefore, based on the results of these studies and our study, TADs can be placed in the interdental space between the maxillary first and second molar (6-7ID) and middle of maxillary first molar (6Middle) rather than placing distal to second molar (7D) as the cortical bone thickness is lesser comparatively which can lead to implant failure due to the lack of primary stability.

Studies by **Park** and **Choi**[12] enumerated that the anatomy of site, especially the thickness and density of the cortical bone, seems to have a direct effect on success rate. Hence a sound knowledge about the site of placement, the quality and the quantity of bone in the maxilla and mandible is essential for us to correlate it clinically. This allows the clinician to plan anchorage strategies and placement of implants with necessary precautions accordingly.

Lin[39] placed miniscrews into the infrazygomatic crest of the maxilla. Presence of sound cortical bone is an important consideration for the clinical success of mini-implant. The results of our study implies that placing the implants in the interdental region between maxillary first and second molar (6-7ID) and between the roots of the first molar (6 Middle) at the height of 10mm and 12mm , which has thicker cortical bone, might aid in achieving primary stability and success of miniscrew implants.

In the beginning of the study we believed in a hypothesis that there is no difference in bone thickness in the infrazygomatic region of first and second molars. But the results of our study concludes that the cortical bone thickness among five different slices at four different heights are highly statistically significant ($p = 0.01$). Thereby disproving the null hypothesis, as there is significant difference in the cortical bone thickness between the maxillary first and second molars in the infrazygomatic region.

The first limitation of our study was that, we were not able to study the sex differences and also the variations in the bone thickness between high angle and low angle cases as the sample size used in our study were too small for statistical comparisons.

The second limitation is that, we did not correlate the bone thickness with various angulations in which the mini-screws are placed. It is an important parameter in the success of mini-implant as it can engage more cortical bone when angulated. this in turn accentuates the primary stability of the implant.

This can be considered a pilot study for future researches in this area and a similar study can be conducted in future with a larger sample size, comparing the individual variations in bone thickness among various malocclusions and also correlate them with the insertion angulations of mini-screw implants.

Summary and Conclusion

SUMMARY AND CONCLUSION

The present in-vitro study was performed to evaluate the amount of cortical bone thickness in the maxillary infrazygomatic region by means of bone mapping using cone beam computed tomography (CBCT). The bone measurements were performed on 40 CBCT images obtained randomly from the database. Measurements were performed in the upper first molar (*6*) and second molar (*7*) region in the following planes, mesial of first molar (*6M*), middle of the crown through the furcation area (*6Middle*), interdental bone between the molars (*6-7ID*), middle of the second molar (*7Middle*), and distal of the second molar (*7D*). The cortical bone thickness was measured along the surface of the infra-zygomatic region at various heights of 8mm, 10mm, 12mm and 14mm from the cemento-enamel junction towards maxillary sinus.

The following conclusions were drawn from the present study:

- The cortical bone thickness among 5 different slices, at 4 different heights were highly statistically significant (p =0.01).
- The cortical bone was thickest at the height of 12 mm from the cementoenamel junction in all five slices.
- The cortical bone was comparatively thinner at the height of 8mm from the cemento-enamel junction in all five slices.

- The interdental region between the maxillary first and second molar (6-7 ID) and the middle of first molar (6Middle) had the thickest cortical bone of 2.36 mm and 2.35 mm respectively.
- The region distal to maxillary second molar (7D) had thinner cortical bone compared to other sites.
- Hence, we have disproved the null hypothesis as there were significant differences in bone thickness between maxillary first and second molar.

Based on the outcome of this study, it is reasonable to conclude that the infrazygomatic region is an optimal extra-alveolar site for placement of Temporary Anchorage Devices (TADs) .The ideal site for insertion of TADs in the infrazygomatic crest are, the interdental region between the maxillary first and second molars (6-7 ID) & the middle of maxillary first molar (6Middle) region at the heights of 10mm and 12 mm. It is better to avoid placing TADs distal to maxillary second molar region as the cortical bone in that region is thinner comparatively.

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Annexures

Annexure – I

RAGAS DENTAL COLLEGE & HOSPITAL
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TO WHOMSOEVER IT MAY CONCERN

Date: 18.12.2017
Place: Chennai

From
The Institutional Review Board,
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The dissertation topic titled **"BONE MAPPING IN THE INFRA ZYGOMATIC REGION FOR IDEAL PLACEMENT OF TADS – A CBCT STUDY"** submitted by **Dr. SWATHY S,** has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

Dr. N.S. Azhagarasan M.D.S,
Member secretary,
Institution Ethics Board,
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Annexure – II

URKUND

Urkund Analysis Result

Analysed Document: SWATHY.docx (D35060038)
Submitted: 1/26/2018 4:43:00 PM
Submitted By: dr.swathyselvaraj@gmail.com
Significance: 3 %

Sources included in the report:

Final thesis.pdf (D34460162)
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